EVOLUTION IN SEMI-DETACHED BINARY SYSTEMS

(Letter to the Editor)

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Abstract. The evolutionary process of semi-detached binary systems is examined on the basis of non-conservation of orbital angular momentum. We conclude that the semi-detached binary systems follow Type B evolution.

1. Introduction

Kippenhahn and Weigert (1967) distinguished between two types of evolution in binary systems–viz that which occurs when the primary fills up its Roche-lobe during the central hydrogen burning phase (Case A), and that in which this occurs after the exhaustion of hydrogen in the core (Case B). The type of evolution that occurs for a binary with given masses of the components depends only on the initial separation of the components; or, what is the same, on the initial period P_0 of the system. If the initial period is shorter than a certain critical value P_{AB} (which depends on initial masses of the components) then the system will evolve according to Case A, and if the initial period is larger, the system will evolve according to Case B. We investigate here the possibility whether the Algol-type binaries are evolving in Case A or in Case B, or both, within the framework of our previous findings that, for the same mass, a semi-detached binary system has orbital angular momentum greater than that of a contact binary system and less than that of a detached binary system (Chaubey, 1979; hereafter referred to as Paper I). Based on the empirical relations between the systemic mass and orbital angular momentum, this latter finding implies that in a close binary system the orbital angular momentum decreases during its evolution.

In this paper the initial periods for 54 Algol-type binaries are calculated using the relations given in Paper I and assuming an initial mass ratio of 1.2, which is the average mass ratio for unevolved binaries.

2. Calculation of Initial Period

According to Paper I, the initial orbital angular momentum H of a binary system can be given by the empirical relation

$$\log H = -1.98 + 1.8 \log M, \tag{1}$$

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TABLE I

Ephemerides of semi-detached binary systems

Binary	P	$M_1/M_\odot$	$M_2/M_\odot$	log M	log P_0	Reference*
RT And	$0^d.629$	1.50	0.98	0.36	0.117	1
TW And	4.123	1.81	0.39	0.34	0.302	1
IM Aur	1.247	2.97	0.89	0.59	0.418	1
Y Cam	3.306	2.33	0.50	0.43	0.227	1
TV Cas	1.816	3.10	1.39	0.65	0.468	1
TW Cas	1.428	2.90	1.18	0.61	0.420	1
RZ Cas	1.195	1.81	0.50	0.36	0.300	1
XY Cep	2.775	3.80	1.10	0.69	0.439	1
GK Cep	0.963	2.72	2.50	0.72	0.464	1
U Cep	2.493	4.20	2.80	0.85	0.502	2
SV Cen	1.659	9.30	11.10	1.31	0.691	2
S Cnc	9.485	5.10	1.80	0.84	0.792	2
U CrB	3.452	4.60	1.20	0.76	0.470	2
KU Cyg	38.439	4.80	0.80	0.75	0.464	2
SW Cyg	4.570	2.80	0.70	0.54	0.382	1
V367 Cyg	18.597	15.60	10.30	1.41	0.730	2
V548 Cyg	1.805	2.74	0.90	0.56	0.384	1
W Del	4.806	2.36	0.47	0.45	0.335	1
AI Dra	1.199	2.18	1.03	0.51	0.520	1
TW Dra	2.803	2.08	0.87	0.47	0.396	1
AS Eri	2.664	2.02	0.25	0.36	0.307	1
S Equ	3.436	2.96	0.36	0.52	0.376	1
U Her	2.051	8.00	2.80	1.03	0.578	1
UX Her	1.549	1.88	0.49	0.37	0.236	1
RX Hya	2.282	1.68	0.40	0.32	0.300	1
CM Lac	1.605	2.01	1.50	0.55	0.410	1
TX Leo	2.445	2.74	1.05	0.58	0.398	1
Y Leo	1.686	1.91	0.63	0.40	0.121	1
CV Leo	0.600	0.99	0.92	0.28	0.270	1
UV Leo	0.600	1.36	1.25	0.42	0.351	1
δ Lib	2.327	2.96	1.31	0.63	0.493	1
β Lyr	12.914	2.00	11.70	1.14	0.621	2
TU Mon	5.049	13.50	2.90	1.21	0.650	2
UX Mon	5.905	3.50	1.50	0.70	0.445	2
TY Peg	3.092	1.50	0.23	0.24	0.107	1
β Per	2.867	3.15	0.74	0.59	0.398	1
RT Per	0.849	1.30	0.31	0.21	0.277	1
ST Per	2.648	2.03	0.39	0.38	0.298	1
Y Psc	3.784	2.09	0.52	0.42	0.358	1
AV Pup	1.126	2.77	2.18	0.69	0.471	1
V Pup	1.475	17.10	9.20	1.42	0.732	2
U Sge	3.381	4.27	1.60	0.79	0.479	2
V Sge	0.514	2.91	0.77	0.57	0.414	1
V505 Sgr	1.183	2.22	1.18	0.53	0.387	1
V356 Sgr	8.896	12.20	4.70	1.23	0.656	2
μ^1 Sco	1.446	14.00	9.20	1.37	0.708	2
V543 Sco	12.004	13.0	22.00	1.54	0.782	2
λ Tau	$3^d.953$	6.90	2.00	0.95	0.544	2
RW Tau	2.769	3.01	0.82	0.58	0.381	1

Table I (continued)

Binary	P	$M_1/M_\odot$	$M_2/M_\odot$	$\log M$	$\log P_0$	Reference*
X Tri	0.972	1.72	1.00	0.43	0.392	1
VV UMa	0.687	1.84	0.45	0.36	0.316	1
TX UMa	3.063	2.80	0.85	0.56	0.377	1
Z Vul	2.455	5.40	2.30	0.89	0.519	2
RS Vul	4.478	4.60	1.40	0.78	0.476	2

*(1) Chaubey (1979). (2) Kreiner and Ziolkowski (1978).

where $M = M_1 + M_2$, is the systemic mass of the binary. However, in the two-body problem, the orbital angular momentum of a binary system with orbital period P is given by the relation

$$H^2 = \left(\frac{G^2}{2\pi}\right)^{1/3} \frac{M_1 M_2}{M^{1/3}} P^{1/3}. \tag{2}$$

Therefore, it is possible to derive the initial period of a binary system of known systemic mass M. Here G denotes the universal gravitational constant and P the observed period.

In this study, the data concerning the masses and the periods are listed in Table I. A plot of the total systemic mass against the computed initial period is given in Figure 1 which also shows the critical period P_{AB} plotted as a function of total mass of the system.

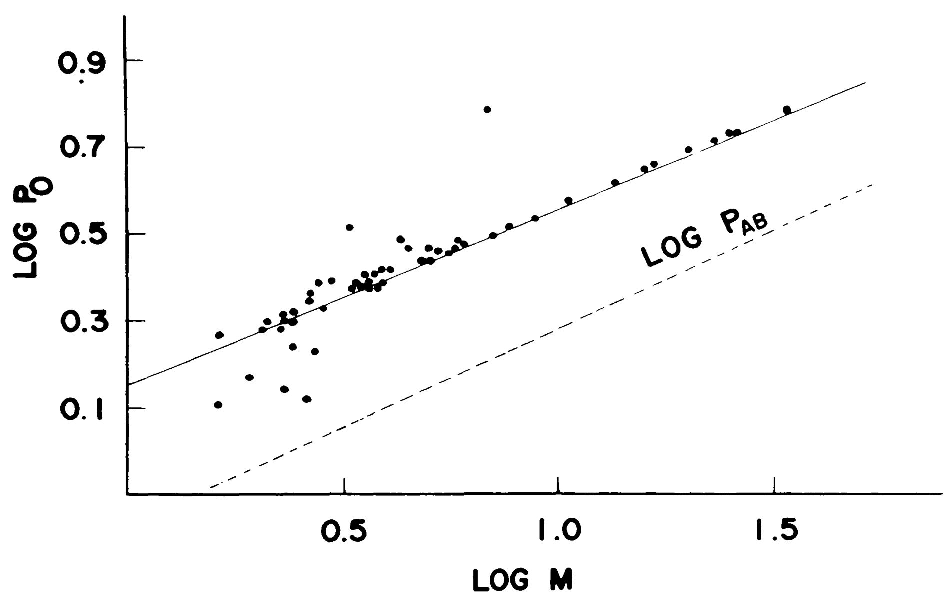

Fig. 1. Initial periods of 54 semi-detached binaries against the total mass of the system.

3. Discussion of the Results

The evolutionary status of Algol-type binaries has been discussed by various investigators. Ziolkowski (1968) suggested that Algol-type systems having systemic mass greater than 5 $M_\odot$ evolve in Case A and those of less than 5 $M_\odot$ follow Case B. Further Ziolkowski (1976) and Kreiner and Ziolkowski (1978) have calculated the initial periods of 18 Algol-type binaries having masses greater than 5 $M_\odot$ (S Cnc, SV Cen, U Cep, U CrB, KU Cyg, V 367 Cyg, U Her, βLyr, TU Mon, UX Mon, V Pup, U Sge, V 356 Sgr, V 453 Sco, μ_1 Sco, λ Tau, Z Vul and RS Vul), on the assumption of the conversation of total mass and total orbital angular momentum of the systems and have concluded that S Cnc, U Cep, KU Cyg, V 367 Cyg, β Lyr, V 356 Sgr, V 453 Sco and U CrB are evolving in Case B and the other 10 systems follow Case A.

However, according to Ziolkowski (1976), the systems positioned in Figure 1 above the line P_{AB} evolve in Case B and those below the line P_{AB} evolve in Case A. Hence all Algol-type binaries, including those studied by Ziolkowski (1976) and Kreiner and Ziolkowski (1978) are evolving in Case B.

The other feature of some interest in data of Table I and Figure 1 is the appearance of a unique relation between the systemic mass and initial period of the system. This relation is:

$$\log P_0 = 0.4 \log M + 0.15. \tag{3}$$

The above equation can be applied in making models of binary X-ray sources.

4. Conclusion

In the framework of our previous findings, this study shows that all the semi-detached binary systems are evolving in Case B.

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